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13. ABSTRACT (Maximum 200 words)
Experimental research has been conducted to demonstrate the potential of the high-temperature superconductors (HTS) for optoelectronics. We performed systematic characterization of femtosecond optical response of superconducting YBa₂Cu₃O_x (YBCO) thin films. We measured, for the first time, 1.5-ps-wide photoresponse signals from an epitaxial YBCO film irradiated with 150 fs optical pulses. Our results shed new light on the nonequilibrium carrier dynamics in HTS, as well as convincingly demonstrated that these materials are suitable for ultrahigh speed optoelectronic applications. We have developed a new, laser-based processing technique (so-called laser writing) for fabrication of HTS optoelectronic devices. The method exploited the contrasting optical and electrical properties of the oxygen-poor (semiconducting) and oxygen-rich (superconducting) YBCO phases and was used to fabricate superconducting structures with various oxygen doping profiles and YBCO photodetectors. Optical measurements were supplemented by extensive transport experiments of both partially oxygen-depleted and photodoped YBCO films. We observed both the persistent and erasable changes of the normal-state transport and superconducting properties of YBCO films, exposed to a prolonged white-light illumination at low temperatures. Our results indicated that both the charge transfer and oxygen ordering mechanisms were responsible for the photoinduced effects in YBCO.

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**ULTRAFAST BROADBAND PHOTODETECTORS FOR HIGH-T_c
SUPERCONDUCTIVE OPTOELECTRONICS**

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RESEARCH FINDINGS

I. Specific Aims and Research Objectives

The main objective of this grant was to demonstrate the potential of the high-temperature superconductors (HTS) for optoelectronics. We presented a new approach for the development of an optoelectronic system, based on HTS films and operational at liquid-nitrogen temperatures. It consisted of exploiting the contrasting optical and electrical properties of the oxygen-deficient and oxygen-rich HTS phases. Our basic physics experiments were aimed to investigate superconducting transport and superconducting fluctuations in HTS materials, especially in case of partially oxygen-depleted materials, when carriers were optically created. The work was intended to have profound implications on the basic-science understanding of nonequilibrium phenomena in strongly perturbed HTS systems. Our applicational goal was to demonstrate optically controlled HTS switches and photodetectors, suitable for ultrafast optical-to-electrical optoelectronic communication links. For this purpose, we proposed to develop a new, laser-based approach to processing of $\text{YBa}_2\text{Cu}_3\text{O}_x$ (YBCO) thin films, exploiting the contrasting optical and electrical properties of the oxygen-poor (semiconducting) and oxygen-rich (superconducting) YBCO phases. Using laser writing, we could fabricate, superconducting structures with nonuniform oxygen doping profiles and photodetectors based on YBCO films containing regions with different oxygen contents. The physical mechanisms behind the performance of our test structures were the focus of our research, since device optimization depended on the result of such basic experiments, as the nonlinear optical properties of HTS films and their high-speed photonic and electronic responses. The performance of HTS photodetectors and their potential for ultrafast optoelectronics was studied via comprehensive time-resolved characterization of the physics of nonequilibrium phenomena in YBCO, perturbed by strong femtosecond optical excitations.

All the above research goals and objectives were realized.

II. Research Accomplishments and Results

II.A. Laser-processing technique

We have developed a laser-processing technique, suitable for fabrication of monolithic YBCO devices. The method is based on the observation that YBCO electrical and optical properties are very sensitive to the material's oxygen content. In particular, we designed a mask-free method for patterning of YBCO films. The patterning was achieved through both laser inhibition, in which an intense, focused laser beam locally melted YBCO transferring it into an insulating glass-like material, and laser writing, based on a laser-controlled diffusion of oxygen in or out of the YBCO film. Using laser inhibition and writing, we were able to fabricate a variety of YBCO devices, showing that laser processing can be successfully used in patterning and/or electrical trimming of multilayered YBCO circuits. Several new analytical techniques, such Raman spectroscopy, optical and scanning electron microscopy, and electrical tunneling and transport measurements were implemented to characterize our laser-processed structures.

The laser-processing technique is noninvasive, does not require a patterning mask, and results in completely planar structures free of surface contamination. We fabricated laser-patterned HTS structures for the collaborative research with the following research institutions: NIST, Boulder, CO; SMU, Dallas, TX; UofHouston, Houston, TX; Imperial College, London, England; Boltzmann Institute, Vienna, Austria; Institute of Physics, Warsaw, Poland; Hebrew University, Jerusalem, Israel; Ben-Gurion University, Beer-Sheva, Israel.

Invention disclosure was submitted on our laser-processing technique. However, the Research Corporation Technologies (UofR patent collaborator) postponed its action due to the fact that (quote) "currently, the market for such a method is limited, making licensing this technology difficult."

II.B. Subpicosecond cryogenic electro-optic sampling system

During the course of this research, we have developed a highly versatile subpicosecond cryogenic electro-optic (EO) sampling system. The complete system consists of a commercial Ti:sapphire laser, pumped by an Ar-ion laser, which is used to excite picosecond pulses in a studied device-under-test (DUT) and, subsequently, electro-optically measure the propagating output transient. The laser provides ~ 100 -fs-wide optical pulses with 800-nm wavelength and 76-MHz repetition rate, at an average power of 1 W. The beam is split into two paths by a 70/30 beamsplitter. The first (excitation) beam (700 mW) is frequency doubled in a nonlinear β -Bariumborate (BBO) crystal, and a reflective filter is used to eliminate the remaining 800-nm light. The excitation beam is intensity modulated by an acousto-optic modulator, and focused by a microscope objective to a 10- μm -diameter spot on the DUT. The microscope objective is also a part of the viewing arrangement which allows us to observe the sample during positioning of the beams. The average optical power of the 400-nm light, measured at a position just outside the dewar, is ~ 2 mW. By measuring the amount of light absorption/reflection in the two dewar windows and the LiTaO_3 crystal, we have found that the incident power is further reduced to ~ 1 mW at the DUT surface, corresponding to a fluence of $17 \mu\text{J}/\text{cm}^2$. Taking the geometry, as well as the reflectance and transmittance of the DUT into account, we estimate the power actually absorbed by the DUT is only $\sim 60 \mu\text{W}$ (fluence $1 \mu\text{J}/\text{cm}^2$). According to our experiments, the corresponding temperature increase is only ~ 0.2 K in our case.

The second (sampling) beam travels through a computer-controlled delay line with $< 1 \mu\text{m}$ resolution and 180 mm total travel, corresponding to a time delay resolution of < 6 fs and a maximum time window of 1200 ps. The beam has ~ 20 mW average power outside the dewar and is focused to a ~ 10 - μm -diameter spot at the gap between the CPW center line and ground plane, only $\sim 20 \mu\text{m}$ from the DUT, where the photoresponse signal is generated. The bottom face of the LiTaO_3 crystal has a dielectric wavelength-selective high-reflectivity (HR) coating, which reflects the 800-nm-wavelength sampling beam but allows the frequency-doubled excitation beam to pass through. The reflected beam has ~ 2 mW average power, and is directed to an analyzer section. The electric field of the propagating (sampled) pulse, which is parallel to a LiTaO_3 crystal axis, induces extra birefringence in the crystal. In the analyzer section, the polarization change due to the birefringence is converted into an intensity change that is measured differentially. The electric-field sensitivity is maximized and linearized by choosing the polarization of the incident sampling beam to a 45° angle with the LiTaO_3 crystal axis and by adjusting the compensator which is placed in the sampling-beam path before the analyzer.

In the electronic part of the EO sampler setup, mixers allow for the use of high-frequency modulation (higher than frequencies where the $1/f$ noise of the laser dominates) and the measurement of the differential signal by a lock-in amplifier. The computer records the time-domain evolution of the electric field at the sampling point by moving the delay stage and measuring the lock-in amplifier output. In typical measurements, averaging of up to 50 traces is used to increase the signal-to-noise ratio. By introducing a known voltage on the CPW and measuring the resulting sampling beam intensity change, the system can be calibrated, so the computer directly calculates and displays the measured signal magnitude in mV.

From a practical point of view, the EO sampler can be regarded as an ultrafast (<300 -fs temporal resolution) and ultrasensitive (<150 - μ V voltage sensitivity) sampling oscilloscope.

II.C. Ultrafast, time-resolved characterization of Y-Ba-Cu-O microbridges

Using the EO sampler presented in Sec. II.B, we have performed exhaustive characterization of optically-thick $7\text{-}\mu\text{m}$ -wide and $10\text{-}\mu\text{m}$ -long superconducting $\text{YBa}_2\text{Cu}_3\text{O}_x$ (YBCO) microbridges, exposed to 150 fs optical pulses and cooled to 79 K (approx. liquid nitrogen temperature). For microbridge fabrication, we used high-quality, 100- and 200-nm-thick epitaxial YBCO films, grown on 0.5-mm-thick, $6 \times 6\text{-mm}^2$ LaAlO_3 substrates using pulsed laser deposition. Several test structures were formed on each chip using a standard photolithographic technique and wet etching in 0.001 M citric acid. The experimental structure consisted of a 4-mm-long CPW with a $30\text{-}\mu\text{m}$ -wide center line and $7\text{-}\mu\text{m}$ -wide gaps to the ground planes. Gold contact pads were deposited in both ends, using *ex situ* evaporation and lift-off. The microbridge was placed in the middle of the CPW center line. Typically, after processing, the bridges exhibited a zero-resistance temperature $T_{c0} > 89$ K, a transition width <2 K, and a critical current density $j_c > 10^6$ A/cm² at 79 K.

The tested sample was mounted on a gold-plated alumina substrate, attached to a copper block inside an exchange-gas, liquid-helium dewar, with optical access through a pair of fused-silica windows. During measurements, the sample was in He exchange gas and the temperature was regulated in the 20- to 80-K range and stabilized to ± 0.2 K by a temperature controller. One end of the CPW was wirebonded directly to a semirigid, 50- Ω coaxial cable, while the other end was wirebonded to ground on the alumina plate. The 1.2-m-long cable brought the signal out of the dewar, and, together with an 18-GHz-bandwidth bias-tee and a 20-GHz-bandwidth amplifier (30-dB gain), allowed us to observe the bolometric part of the bridge response on a 14-GHz-bandwidth oscilloscope.

The measured transients for superconducting microbridges were 1.5-ps-wide and their amplitude varied linearly with the bias current, demonstrating a superconductive kinetic inductive mechanism. The main pulse was followed by a few-ps-long negative transient, demonstrating an evidence for nonequilibrium recombination of excited quasiparticles into Cooper pairs. The signal generated from a detector in the switched (resistive) state had a near-Gaussian shape and was 1.1-ps-wide. Essentially the same waveforms with full-widths at half-maximum ranging from 1.1 to 1.3 ps were observed at all tested temperatures in the 20- to 80-K range, suggesting that the response was not directly related to the (above T_c) hot spot temperature. After the picosecond transient, we observed an approximately 200- μ V-level plateau (on the 1 ps/div. time scale) associated with the slow bolometric response. The picosecond transient is superimposed on this very

slow tail, which we simultaneously observed on a 14-GHz bandwidth oscilloscope. The bolometric response had $\sim 250\text{-}\mu\text{V}$ amplitude and a few nanosecond fall time.

Our experiments showed that YBCO is definitely suitable for ultrafast optoelectronic applications. They also illustrated our general concept of the combined superconducting/optical technology for ultrahigh performance computation and communication.

The above research was done in a very close collaboration with the McMaster University, Hamilton, Ontario, Canada.

II.D. Femtosecond pump-probe experiments—technique and results

Nonequilibrium processes are conveniently investigated by the use of all-optical pump-probe techniques. A femtosecond laser pulse was used by us to induce nonequilibrium conditions in the tested YBCO material and a second time-delayed pulse was used to measure the induced change in either reflectance or transmittance of the film. The electron and phonon temperatures were subsequently related to the change in reflectivity, using the so-called smearing model of the hot-electron distribution at the Fermi surface.

Our femtosecond pump-probe measurements demonstrated the existence of an ultrafast (subpicosecond) optical response in HTS materials. In particular, our results have shown: (i) the optical response of YBCO is primarily bolometric at $T > T_c$ under all levels of excitation, and at $T < T_c$ under the high excitation level; (ii) the optical nonbolometric response existed at $T < T_c$ under low level of excitation and could not be completely accounted by the simple two-fluid model; and (iii) the femtosecond response of the oxygen-poor YBCO was qualitatively different from that of the oxygen-rich material. Although it is necessary to have a detailed understanding of the energy band structure in order to convert the reflectivity data into a time-dependent electron temperature, our data showed that the smearing model was fully applicable in YBCO films with oxygen content above that corresponding to the metal-insulator transition. The Fermi-energy level (E_F) was dependent on the oxygen doping in YBCO and shifted downward (in the hole picture) as the oxygen content decreased. The position of E_F was approximately 2 eV above the d^9/d^{10} band for films with $T_c \approx 60$ K. Finally, pump-probe experiments have also shown that the nonequilibrium photoresponse without a thermal (bolometric) background could be observed in superconducting YBCO only under very low-fluence conditions.

II.E. Superconducting transport, magnetoresistance, and photodoping measurements in HTS thin films with reduced oxygen content

Our laser-processing technique (Sec. II.A) was used to pattern 110-K phase BSCCO films and partially oxygen-depleted ($T_c \approx 60$ K) YBCO samples for studies on normal-state magnetotransport properties, superconducting fluctuations, and the photodoping effect. Measurements of the electrical resistivity, the magnetoresistance, and the Hall effect were analyzed with regard to contributions of the superconducting order-parameter thermodynamic fluctuations, using theories for two-dimensional, layered superconductors. We have found a consisted set of transport parameters for BSCCO, such as in-plane and out-of-plane coherence lengths and the electron-hole asymmetry. The rapid suppression of the Maki-Thompson process for the oxygen-deficient YBCO films, indicated an unconventional symmetry of the superconducting order parameter.

Extensive transport measurements were done for both partially oxygen-depleted and photodoped YBCO films. We have measured both the persistent and erasable photoinduced changes of the normal-state transport, and superconducting properties of YBCO films. After illumination with white light for several hours at 150 K, a decrease of the electrical resistivity, an increase of the number of mobile holes, a change of the magnetoresistance, and an enhancement of the superconducting coherence lengths in both in-plane and out-of-plane directions were observed. Our results indicated that both the charge transfer and oxygen ordering mechanisms were responsible for the photoinduced effects in YBCO. Our transport measurements also showed that in partially oxygen-deficient films, magnetoresistance was solely caused by the magnetic-field suppression of superconducting order-parameter fluctuations, existing in the films up to 143 K, i.e., $2.6 T_c$. Again, no signature of the Maki-Thompson fluctuation process or a magnetoresistance resulting from the cyclotron motion of the normal-state quasiparticles was found.

Finally, we introduced the first *in-situ* transport measurements, in which both the longitudinal and transverse (Hall) resistivities of our samples were measured *during* the photodoping experiments. The *in-situ* studies on photodoping effect in partially oxygen-depleted YBCO films demonstrated the enhancement of the film critical temperature dependence on both the photodoping temperature and the light dose. This latter effect can have important implications for light-induced superconductivity and light-controlled optoelectronic HTS devices.

The above research was done in a very close collaboration with the Ludwig Boltzmann Institute for Solid State Physics, Vienna, Austria.

III. Summary of the Most Important Results

Experimental research has been conducted to demonstrate the potential of the high-temperature superconductors (HTS) for optoelectronics. We performed systematic characterization of femtosecond optical response of superconducting $\text{YBa}_2\text{Cu}_3\text{O}_x$ (YBCO) thin films. We measured, for the first time, 1.5-ps-wide photoresponse signals from an epitaxial YBCO film irradiated with 150 fs optical pulses. Our results shed new light on the nonequilibrium carrier dynamics in HTS, as well as convincingly demonstrated that these materials are suitable for ultrahigh speed optoelectronic applications. We have developed a new, laser-based processing technique (so-called laser writing) for fabrication of HTS optoelectronic devices. The method exploited the contrasting optical and electrical properties of the oxygen-poor (semiconducting) and oxygen-rich (superconducting) YBCO phases, and was used to fabricate superconducting structures with various oxygen doping profiles and YBCO photodetectors. Optical measurements were supplemented by extensive transport experiments of both partially oxygen-depleted and photodoped YBCO films. We observed both the persistent and erasable changes of the normal-state transport and superconducting properties of YBCO films, exposed to a prolonged white-light illumination at low temperatures. Our results indicate that both the charge transfer and oxygen ordering mechanisms are responsible for the photoinduced effects in YBCO.

IV. Impact on Applications of Superconductivity

Optoelectronics emerges as one of the most important engineering disciplines of the XXI century. In this context, the development of superconducting optoelectronics becomes also crucial, since it offers (similarly to superconducting electronics) the lowest value of the switching-time-power-consumption product. As we have shown, YBCO material has an number of very interesting and applicable for optoelectronics, optically-induced effects. Simple YBCO photodetectors exhibit single-picosecond response times, making them not only one of the fastest, but, clearly, the cheapest optoelectronic switches. The operating temperature range of YBCO devices enables the full integration with both the superconducting and the conventional (cooled) semiconductor electronics.

V. Professional Personnel Directly Involved and Supported Under the Grant

Roman Sobolewski (PI) - full time

During the grant period, Dr. Sobolewski was promoted from the rank of Scientist and Adjunct Associate Professor of Electrical Engineering to the Senior Scientist and Professor of Electrical Engineering and Senior Scientist of Laser Energetics.

Philippe M. Fauchet (coPI) - part time

During the grant period, Dr. Fauchet was promoted from the rank of an Associate Professor of Electrical Engineering to the Professor of Electrical Engineering and Senior Scientist of Laser Energetics.

Mikael Lindgren (post-doc) - full time

Dr. Lindgren completed his 2-year post-doctoral training and left university for a permanent staff position at the Saab Aerospace Co, Gothenburg, Sweden.

Ting Gong (post-doc) - part time

Dr. Gong was involved in early stages of this project and left university for a private business job.

Frank Hegmann (post-doc) - part time

Dr. Hegmann visited our group for 3 months, while associated with McMaster University, Hamilton, Ont., Canada.

Witold Kula (post-doc) - part time

Dr. Kula completed his post-doctoral training and left university for a permanent staff position at the CVC Products Inc., Rochester, NY.

Wei Xiong (grad. student) - not directly supported

Dr. Xiong graduated (Ph.D. and M.S. degrees) with honors in 1995 and left for a permanent staff position to the Materials Research Corporation (SONY subsidiary), Orangeburg, NY. As a graduate student, Xiong was supported by the Frank Horton Laboratory for Laser Energetics Fellowship Program.

Di Wu (grad. Student) - not directly supported

Mr. Wu received M.S. degree in Electrical Engineering through a non-thesis M.S. program.

Tamara Kroll (grad. student) - not directly supported
Ms. Kroll received M.S. degree in Electrical Engineering through a non-thesis M.S. program.

Ahmed Shahid (undergraduate student) - summer support
Mr. Shahid participated in the Summer Research Program for undergraduate students.

VI. Thesis and Publications

Ph.D. THESIS (1995)

Wei Xiong, "Fabrication and Optoelectronic Properties of Y-Ba-Cu-O Thin Films with Different Oxygen Contents," Department of Electrical Engineering, University of Rochester, Rochester, NY 14627.

The following publications with the grant acknowledgment appeared in print:

1. "Femtosecond Reflectivity of 60-K Y-Ba-Cu-O Thin Films," L. Shi, T. Gong, W. Xiong, X. Weng, R. Sobolewski, and P. M. Fauchet, Appl. Phys. Lett. **64**, 1150-1152 (1994).
2. "Superconducting Fluctuations: Paraconductivity, Excess Hall Effect, and Magnetoconductivity in 2223-BiSrCaCuO Thin Films," W. Lang, W. Kula, and R. Sobolewski, Physica B **194-196**, 1643-1644 (1994).
3. "Femtosecond Optical Response of Y-Ba-Cu-O Films and Their Applications in Optoelectronics," R. Sobolewski, L. Shi, T. Gong, W. Xiong, X. Weng, Y. Kostoulas, and P. M. Fauchet, (INVITED) in: High-Temperature Superconducting Detectors: Bolometric and Nonbolometric, edited by M. Nahum and J.-C. Villegier, Proc. SPIE, vol. 2159, pp. 110-120 (1994).
4. "Transport Properties and Superconducting Fluctuations in Oxygen Deficient Y-Ba-Cu-O Thin Films," W. Göb, W. Lang, W. Kula, and R. Sobolewski, Physica C **235-240**, 1535-1536 (1994).
5. "Femtosecond Optical Spectroscopy of Partially Deoxygenated Y-Ba-Cu-O Thin Films," L. Shi, T. Gong, W. Xiong, X. Weng, R. Sobolewski, and P. M. Fauchet, in Ultrafast Phenomena IX, edited by P. F. Barbara, W. H. Knox, G. A. Mourou, and A. H. Zewail, Springer Series in Chemical Physics (Springer-Verlag, Berlin, Heidelberg, 1994), vol. 60, p. 327.
6. "Formation and Relaxation of Persistent Photoconductivity in Oxygen-Deficient YBa₂Cu₃O_x," C. Stockinger, W. Markowitsch, W. Göb, W. Lang, W. Kula, and R. Sobolewski, in: Applied Superconductivity 1995, Institute of Physics Conference Series Number 148, edited by D. Dew-Hughes, Institute of Physics Publishing (Bristol, 1995), pp. 975-978.
7. "Superconducting and Normal-State Properties of Oxygen-Deficient YBa₂Cu₃O_x Thin Films Under Light Illumination," W. Göb, W. Lang, W. Markowitsch, C. Stockinger, W. Kula, and R. Sobolewski, in: Applied Superconductivity 1995, Institute of Physics Conference Series Number 148, edited by D. Dew-Hughes, Institute of Physics Publishing (Bristol, 1995), pp. 979-982.
8. "Anisotropic Magnetoresistance in the Normal State of Oxygen-Deficient Y-Ba-Cu-O Thin Films Induced by Superconducting Fluctuations," W. Lang, W. Göb, W. Kula, and R. Sobolewski, Z. Phys. B **98**, 453-456 (1995).

9. "Erasable Photoinduced Change of Carrier Density and Coherence Lengths in Oxygen-Deficient $\text{YBa}_2\text{Cu}_3\text{O}_x$," W. Göb, W. Lang, W. Markowitsch, V. Schlosser, W. Kula, and R. Sobolewski, Solid St. Commun. **96**, 431-435 (1995).
10. "Electro-Optic Sampling of Picosecond Photoresponse of Epitaxial $\text{YBa}_2\text{Cu}_3\text{O}_{7-x}$ Thin Films," F. A. Hegmann, S. H. Moffat, R. A. Hughes, J. S. Preston, D. Jacobs-Perkins, C.-C. Wang, T. Y. Hsiang, and R. Sobolewski, in Ultrafast Electronics and Optoelectronics vol. 13, 1995 OSA Technical Digest Series, (Optical Society of America, Washington D.C., 1995), pp. 49-51.
11. "Electro-Optic Sampling of 1.5-ps Photoresponse Signals from $\text{YBa}_2\text{Cu}_3\text{O}_{7-x}$ Thin Films," F. A. Hegmann, D. Jacobs-Perkins, S. H. Moffat, C.-C. Wang, R. A. Hughes, M. Currie, P.M. Fauchet, T. Y. Hsiang, J. S. Preston, and R. Sobolewski, Appl. Phys. Lett. **67**, 285-287 (1995).
12. "Photodoping and Relaxation of Persistent Photoconductivity in $\text{YBa}_2\text{Cu}_3\text{O}_x$, Studied by *In-situ* Transport Measurements," C. Stockinger, W. Markowitsch, W. Lang, W. Kula, and R. Sobolewski, J. Low Temp. Phys. **105**, 1403-1408 (1996).
13. "In-situ Resistivity and Hall Effect Studies of Persistent Photoconductivity in Oxygen-Depleted $\text{YBa}_2\text{Cu}_3\text{O}_x$, (INVITED)" W. Markowitsch, C. Stockinger, W. Lang, W. Kula, and R. Sobolewski, in: Spectroscopic Studies of Superconductors, Proc. SPIE. **2696**, 187 (1996).
14. "Dynamics of Photodoping and Photoconductivity Relaxation in Oxygen-Deficient $\text{YBa}_2\text{Cu}_3\text{O}_x$," W. Markowitsch, C. Stockinger, W. Göb, W. Lang, W. Kula, and R. Sobolewski, Physica C **265**, 187-193 (1996).
15. "Picosecond Photoresponse of $\text{YBa}_2\text{Cu}_3\text{O}_{7-x}$ Thin Films," M. Lindgren, M. Currie, C. Williams, S. H. Moffat, R. A. Hughes, F. A. Hegmann, J. S. Preston, T. Y. Hsiang and R. Sobolewski, Czech. J. Phys. **46**, 1111-1112 (1996).
16. " $\text{YBa}_2\text{Cu}_3\text{O}_{7-x}$ Thin-Film Picosecond Photoresponse in the Resistive State," M. Lindgren, M. Currie, C. Williams, S. H. Moffat, R. A. Hughes, F. A. Hegmann, J. S. Preston, T. Y. Hsiang and R. Sobolewski, IEEE Trans. Appl. Supercon. **7**, 3422-3425 (1997).

VII. Conferences and Major Seminars

Invited conference presentations:

1. "Femtosecond Optical Response of Y-Ba-Cu-O Films and Their Applications in Optoelectronics," R. Sobolewski, L. Shi, T. Gong, W. Xiong, X. Weng, Y. Kostoulas, and P. M. Fauchet, presented at the SPIE International Symposium on Optoelectronics for Information and Microwave Systems—High-Temperature Superconducting Detectors: Bolometric and Nonbolometric, Los Angeles, CA, 1994.
2. "Femtosecond Lasers in Science and Engineering," R. Sobolewski, presented at the International Conference on Lasers and Applications—Advances in Science, Medicine, and Technology, Cairo, Egypt, 1994.
3. "Progress in Ultrafast Superconducting Electronics," R. Sobolewski, presented at the International Workshop on Superconductivity and Particle Detection, Toledo, Spain, 1994.
4. "Future Prospects for High Temperature Superconducting Electronics and Optoelectronics," R. Sobolewski, presented at the Austrian Workshop on High Temperature Superconductors, Obertauern, Austria, 1994.

5. "Study of Superconducting Fluctuations in the High-Temperature Superconductors YBCO and BSCCO by Magneto-Transport Measurements," W. Lang, C. Sekirnjak, G. Heine, P. Schwab, S. Proyer, D. Bauerle, W. Kula, and R. Sobolewski, presented at the International Conference of Science and Technology of Synthetic Metals, ICSM'94, Seoul, Korea, 1994.
6. "Cryogenic Optoelectronic Measurements of Single-Flux-Quantum Pulses in Superconducting Circuits," C.-C. Wang, M. Currie, D. Jacobs-Perkins, R. Sobolewski, T. Y. Hsiang, and M. J. Feldman, presented at the 1995 International Semiconductor Device Research Symposium, ISDRS'95, Charlottesville, VA, Dec. 1995.
7. "Ultrafast Characterization of Superconducting Materials and Devices," R. Sobolewski, presented at the 9th International Symposium on Ultrafast Phenomena in Semiconductors, UFPS'95, Vilnius, Lithuania, 1995.
8. "Electro-Optic Measurements of Single-Flux-Quantum Pulses," C.-C. Wang, M. Currie, D. Jacobs-Perkins, R. Sobolewski, T. Y. Hsiang, and M. J. Feldman, presented at the European Conference on Applied Superconductivity, EUCAS'95, Edinburgh, Scotland, 1995.
9. "In-situ Resistivity and Hall Effect Studies of Persistent Photoconductivity in Oxygen-Depleted $\text{YBa}_2\text{Cu}_3\text{O}_x$," W. Markowitsch, C. Stockinger, W. Lang, W. Kula, and R. Sobolewski, presented at the Photonics WEST, SPIE International Symposium on Integrated Optoelectronics (OE/LASE'96) - Spectroscopic Studies of Superconductors, San Jose, CA, 1996.
10. "Picosecond Photoresponse of Y-Ba-Cu-O Films and Their Applications in Optoelectronics," R. Sobolewski, presented at the International Weak Superconductivity Symposium, WSS'96, Smolenice, Slovakia, Aug. 1996.

In addition, Contributed Communications were presented at 15 international and 9 local (Western New York) conferences.

Major seminars and lectures:

1. "Electro-Optic Time Domain Characterization of Ultrafast Devices and Transmission Structures," the Department of Physics, Ben-Gurion University of the Negev, Beer-Sheva, Israel, January 1993.
2. "High Temperature Superconducting Optoelectronics," presented at the Institute of Physics, Polish Academy of Sciences, Warszawa, Poland, January 1993.
3. "Laser Writing: A New Technique for Fabrication of Electronic and Optoelectronic Y-Ba-Cu-O Devices and Circuits," presented at the Westinghouse Science and Technology Center, Pittsburgh, PA, December 1993.
4. "Electrical and Optical Properties of Superconducting Y-Ba-Cu-O Thin Films," presented at the Department of Physics, University of Salamanca, Salamanca, Spain, April 1994.
5. "Ultrafast Characterization of Superconducting Materials and Devices," presented at the Physics Department, Imperial College, London, UK, July 1995.
6. "Ultrafast Characterization of Superconducting Materials and Devices," presented at the Quantum Metrology Group, National Physical Laboratory, Teddington, UK, July 1995.
7. "Ultrafast Superconducting Electronics," presented at the Laboratory for Laser Energetics, University of Rochester, Rochester, NY, February 1996.
8. "Picosecond Photoresponse of Y-Ba-Cu-O Films and Their Applications in Optoelectronics," R. Sobolewski, presented at the Ludwig Boltzmann Institute for Solid State Physics, Vienna, Austria, August 1996.

One-Day ARO Review Meeting on Ultrafast Superconducting Optoelectronics
(Aug. 23, 1994, Rochester, NY):

ARO Representative: Dr. H. Everitt

Review Presentations:

R. Sobolewski	Introduction and Femtosecond Spectroscopy of Superconducting YBCO Thin Films
P. M. Fauchet	IR-to-UV Femtosecond Laser Facility and Its Impact on the HTS Research
W. Kula	Optical Processing of YBCO and Photoinduced Superconductivity
W. Xiong	Optical Properties of Oxygen-Poor YBCO and Its Application for Broadband Photodetectors
W. R. Donaldson	LLE Omega Upgrade Presentation

VIII. Interactions

We pursued active research interactions and collaborations with the following institutions:

1. Northrop Grumman Science & Technology Center, Pittsburgh, PA.
2. TRW Space and Technology Group, Rodendo Beach, CA.
3. NIST, Boulder, CO.
4. SUPERCONIX, Inc., St. Paul, MI.
5. Texas Center for Superconductivity, Houston, TX.
6. Wright Laboratory, WPAFB, OH.
7. Boltzmann Institute for Solid State Physics, Vienna, Austria.
8. Centre for High- T_c Superconductivity at the Imperial College, London, UK.
9. Southern Methodist University, Dallas, TX.
10. Institute of Physics, Polish Academy of Sciences, Warsaw, Poland.
11. Hebrew University, Jerusalem, Israel.
12. Ben-Gurion University, Beer-Sheva, Israel.

IX. Honors, professional activities, and awards

1. Dr. Sobolewski was the member of the International Advisory Committee of the 9th International Symposium on Ultrafast Phenomena in Solids, Vilnius, Lithuania, 1995. He was also voted the Member of the International Advisory Committee of the 1998 Symposium.
3. Dr. Sobolewski is an expert for the United Nations Development Programme (UMBRELLA Project -*Advisory Assistance to Poland*).
4. Dr. Sobolewski is a reviewer for the National Science Foundation, the International Science Foundation, and the Air Force Office for Scientific Research and the referee for the Phys. Rev. Lett., Phys. Rev. B, Appl. Phys. Lett., J. Appl. Phys., IEEE Trans. Electron. Devices, and IEEE Trans. Appl. Supercon.
5. Dr. Sobolewski is a "Mentor" for the Ronald E. McNair Post-Baccalaureate Achievement Program.
6. Dr. Sobolewski is the Vice-Chair of the Rochester Chapter of IEEE Electron Device Society.